Photons & Fusion

July 2011

Photons & Fusion *is a monthly review of science and technology at the National Ignition Facility & Photon Science Directorate. For more information,* submit a question.

LIFE Papers Detail Plans for Laser Fusion Energy

A series of eight papers describing aspects of LLNL's Laser Inertial Fusion Energy (LIFE) concept was published in the July issue of the American Nuclear Society journal, *Fusion Science and Technology* (*Fusion Science and Technology* 60 (2011)). Published as the proceedings from last November's 19th Topical Meeting on the Technology of Fusion Energy, the papers include an overview of NIF by NIF Director Ed Moses, a description of a LIFE power plant, and the path to timely delivery of commercial inertial fusion energy by NIF&PS Director for Laser Fusion Energy Mike Dunne. Much of the information in the papers is available on the new LIFE Website.

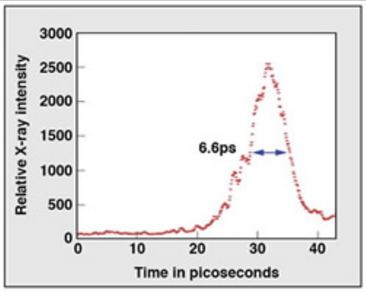
Artist's rendering of a LIFE power plant.

A Faster X-ray Camera for NIF

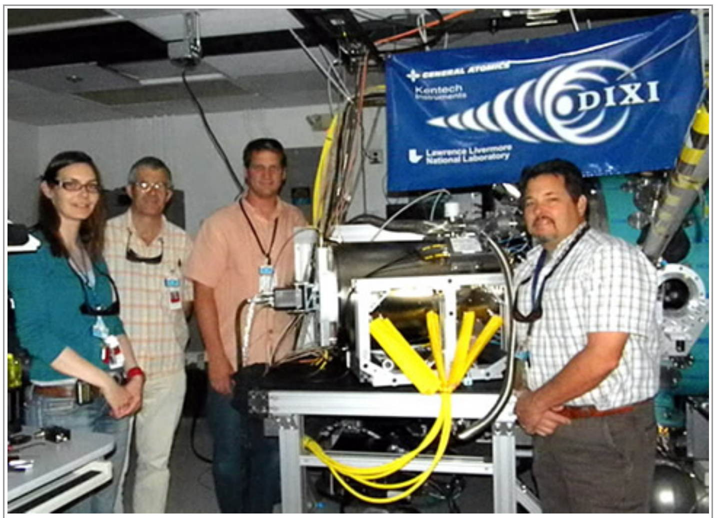
The X-ray cameras on inertial confinement fusion facilities can determine the implosion velocity and symmetry of NIF targets by recording the emission of X-rays from the target gated as a function of time. Based on a technology originally developed at LLNL, these cameras have practical shutter times of a little less than 100 picoseconds (trillionths of a second), which is adequate for present applications.

To capture targets that undergo ignition and thermonuclear burn, however, cameras with tenfold faster shutter times are needed. A collaboration between LLNL, General Atomics and Kentech Instruments has resulted in the design and construction of an X-ray camera with a shutter time shorter than ten picoseconds. Recently tested on the COMET short-pulse laser facility at LLNL, the Dilation X-ray Imager (DIXI) camera converts an X-ray image to an electron image, which is dilated, or stretched, and then coupled to a conventional shuttered electron camera. This process results in a much shorter effective shutter speed.

This was tested on COMET, where a ten-joule laser pulse less than one picosecond in duration was focused onto an aluminum-coated titanium target and produced a short burst of X-rays, as shown in the figure above. Having demonstrated that it can operate with X-ray illumination in a laser environment, DIXI will be installed on NIF over the next few months.



The time history of the X-ray emission from an experiment demonstrating sub-picosecond X-ray gating measured by the Dilation X-ray Imager.



The Dilation X-ray Imager (DIXI) was installed on the target chamber at LLNL's COMET laser facility and operated by a research team composed of (from left): Sabrina Nagel of LLNL, Jonathan Hares of Kentech Instruments, Terry Hilsabeck of General Atomics, and Jim Emig of LLNL.

Capsule Shell Conditions in Laser-Driven Implosions

To achieve the level of compression of deuterium-tritium fuel needed for ignition, NIF's lasers are fired in a series of four coalescing shock waves.

The timing and strength of these shocks are important for compressing the solid-density target in order to achieve an implosion with minimal entropy (low internal pressure and temperature).

In an article in the July 1 edition of *Physical Review Letters* (doi:10.1103/*PhysRevLett*.107.015002), LLNL researchers report on the first simultaneous measurement of the electron density and electron temperature of spherically converging matter through the use of spectrally resolved X-ray Thomson scattering, or the scattering of electromagnetic radiation from the plasma in the fuel capsule (scattering occurs when a probe photon source scatters from electrons in the plasma). In experiments at the OMEGA laser facility at the University of Rochester, the researchers measured the shell conditions of spherically compressed plastic and beryllium capsules. The measurements show that laser pulse shape tuning can be used to optimize the performance needed to reach ignition conditions for both types of capsules.

Contributing to the article were Andrea Kritcher, Tilo Döppner, Carsten Fortmann, Tammy Ma, Otto (Nino) Landen, Russell Wallace, and Siegfried Glenzer.

Noted Photographer Captures NIC Preparations

Award-winning *National Geographic* photographer Joe McNally and his team spent five days in early July completing an extensive photo shoot at NIF. McNally, who took an iconic *National Geographic* "human fly" photo of a worker scaling the inside of the NIF Target Chamber in 2001, was also at NIF last year to photograph the laser bays and optics assembly area.

Surrounded by NIF diagnostics, National Geographic photographer Joe McNally (left) takes close-up photos of the Target Chamber interior from the boomlift, accompanied by target area operator John Bower.

For this month's shoot, McNally was able to access the interior of the Target Chamber via the boomlift, as well as the access port. He also photographed the target assembly area and NIF workers performing maintenance in the Target Bay. McNally's photo spread is expected to run in the magazine early next year.

Laser-Energy 'Maps' Predict NIF Optics Lifetimes

The lifetime of NIF's optics depends on the number of sites where damage has been initiated and on how fast these sites grow during repeated laser shots. This information is important for deciding when to pull out an optic for repair in the optics mitigation facilities. High-intensity hot spots – large variations in the fluence (energy per unit area) of the NIF lasers – are important features that can cause damage sites to grow.

In an article in the July 10 issue of *Applied Optics* (doi:10.1364/AO.50.003547), NIF&PS researchers describe how they used measured shot-to-shot variations in the laser fluence to develop a new statistical model to predict the maximum fluence to which any particular location will be exposed after a given number (N) of shots. The resulting "max-of-N" fluence "map" can be used to accurately calculate the number of damage initiation sites and thus, the useful lifetime of the optic before recycling or repair is required.

Contributing to the article were researchers Zhi Liao, John Huebel, John Trenholme, Ken Manes, and C. Wren Carr.

NIF Vacuum Systems Described at ORNL Workshop

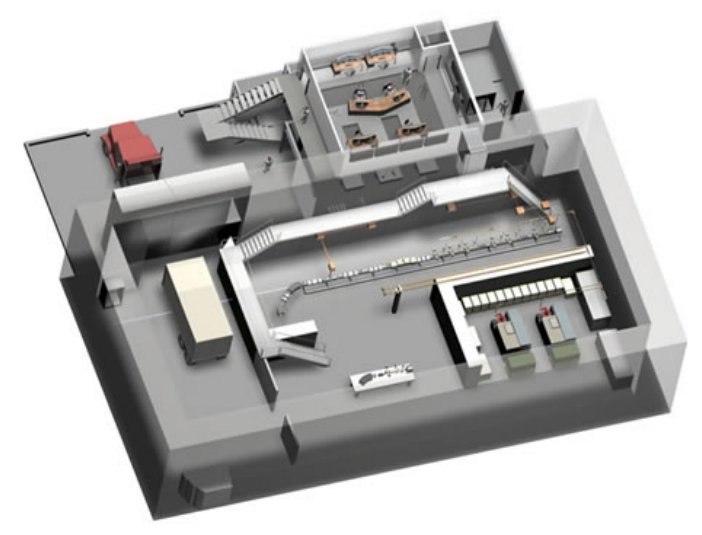
A detailed description of the many vacuum systems used on NIF was presented by Igor Maslennikov and his fellow vacuum subsystems managers – John Hitchcock, William Collins and Farhad Fereydouni – at an Operation of Large Vacuum Systems Workshop held July 11 to 14 at Oak Ridge National Laboratory in Tennessee.

Igor Maslennikov inspects a Target Chamber vacuum pump.

The presentation discussed the two major groups of NIF vacuum systems – those in the laser bays, such as the spatial filter vacuum system, and those servicing the Target Bay. It also described their operational requirements, including the need to pump the 550,000-liter Target Chamber down to high vacuum (about 10^{-6} Torr) in about one hour. The systems also must deal with large surface areas susceptible to outgassing due to the many cables and other utilities required for NIF's target positioners and diagnostics.

MEGa-ray Research Highlighted at INMM Meeting

A number of LLNL researchers participated in the Institute of Nuclear Materials Management (INMM) annual meeting, held July 17-21 in Palm Desert, CA. Several presentations highlighted aspects of the Laboratory's work on mono-energetic gamma ray (MEGa-ray) light sources.



Conceptual design of a mono-energetic gamma-ray, or MEGa-ray, facility.

A presentation by NIF&PS Chief Technology Officer Chris Barty and his colleagues from the Photon Science and Applications Division reviewed the design, optimization and development of past and future MEGa-ray machines and surveyed the range of nuclear applications being pursued with them at LLNL. The presentation reviewed in detail the ongoing efforts at LLNL to create a first-of-its-kind, compact, tunable MEGa-ray source whose flux will be up to five orders of magnitude higher and have a bandwidth two orders of magnitude narrower than any existing MEGa-ray capability.

In other presentations, Felicie Albert and colleagues described nuclear resonance fluorescence (NRF)-based applications of LLNL's T-REX (Thomson-Radiated Extreme X-ray) MEGa-ray source; and Scott G. Anderson and colleagues discussed the use of X-band technology in the Lab's gamma-ray source.

LIFE Reviewed by Electric Power Research Institute

On July 20, the Laser Inertial Fusion Energy (LIFE) team presented plans for building a fleet of power stations to the electric power industry at Electric Power Research Institute (EPRI) headquarters in Palo Alto, CA. The LLNL LIFE team was joined by the Laboratory's partners from industry and other national labs. The team described the design of the LIFE plant, the technology delivery plan, and the economics of LIFE. The purpose of the review was to inform the utility industry of the status of laser fusion research and the prospects for near-term commercialization of the technology. Output from the review is expected later this calendar year.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Ultra-Thin Membrane Optic for Orbital Surveillance

Photon Science & Applications (PS&A)'s first diffractive membrane optic, designed for a Defense Department project aimed at conducting space-based video surveillance, was completed on July 25.

The lightweight primary optic – a wafer-thin segmented lens that would unfurl in orbit – was designed in partnership with Ball Aerospace and Nexsolve Corp. for the Defense Advanced Research Project Agency's Membrane Optical Imager for Real-Time Exploitation (MOIRE) program.

Mike Aasen holds the first diffractive membrane optic for the MOIRE imager. Multiple images of Tom Carlson appear behind the optic, which was designed and verified to achieve greater than 30 percent efficiency for the image used by the telescope.

The program is intended to provide tactical video surveillance from a satellite in geosynchronous orbit. The 80-centimeter-diameter, 18-micron-thick diffractive membrane with four-micron-wide critical dimensions was printed and etched using PS&A's diffractive optic manufacturing capabilities. It will be tested at Ball Aerospace facilities in early demonstrations of the MOIRE technology.

Lindl and Rosen Honored with DMTS Designation

NIF & Photon Science Chief Scientist John Lindl and veteran laser physicist Mordy Rosen have been named Distinguished Members of Technical Staff (DMTS) for their extraordinary scientific and technical contributions to the Laboratory and its missions, as acknowledged by their professional peers and the larger scientific community.

Lindl has more than 38 years of exceptional contributions in plasma physics, high energy density physics and inertial confinement fusion research, as well as significant scientific management experience. His integrated model for ignition served as the basis for the Nova Laser program, which was designed to test the key physics issues and to ultimately set the design requirements for the National Ignition Facility.

John Lindl

Rosen's 35-year career at the Laboratory began when he was hired by former Director John Nuckolls into X-Division (ICF design) in 1976. Not only did Rosen design the first demonstrated Laboratory soft X-ray laser in 1984, he led X-Division during the 1990s when the Nova Technical Contract was completed. His work helped form the foundation for the national science-based stockpile stewardship effort and led to DOE's final approval of NIF construction.

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Mordy Rosen